Analysis of Cognitive Radio Networks with Balking and Reneging

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Abstract. In this paper, we investigate the concept of balking and reneging on Cognitive Radio Networks. The concept of balking and reneging is quite common in the networking world nowadays. The more occupied the system, the more discouraged are the new coming customers, on the other hand, impatient users will leave the system after a maximum waiting time.

Keywords: Finite source queuing systems · Simulation · Cognitive Radio Networks · Performance measures · Balking · Reneging

1 Introduction

The primary goal of our model "Cognitive Radio Network" is to make use of the free spaces of the primary frequency band for the benefit of the secondary one. [1–6] and [7] provide more details.

Two elements are considered in our queuing system, the first one is designed for Primary Users (PU) with a limited number of sources that generate primary calls after an exponentially distributed time. All the generated calls will join a FIFO queue to get served. The service time is exponentially distributed. The second subsystem is dedicated to the jobs of the Secondary Users (SU) generated by a finite number of sources and headed to the Secondary Channel Service (SCS) to be serviced. The arrival time of these calls is exponentially distributed, however, their service time is generally distributed using hypo-exponential, hyper-exponential and gamma distributions.

The generated licensed calls will check the availability of the Primary Channel Service (PCS), if it is free, the service might start straight away, if it is occupied with a primary call the later call will join the FIFO queue. However, if this PCS is taken by a secondary customer, its service stops immediately and will be directed back to the SCS. Depending on the current situation of the secondary

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service unit, the aborted call will restart from the beginning its service or will be added to the retrial queue (orbit).

On the other hand, SCS receives unlicensed requests. Supposing the intended server is idle, SU is allowed to start the service, if it is occupied, they might try opportunistically to start their service in the PCS. If the last service channel is not occupied, the low priority might have the opportunity to start the service, otherwise, if it is occupied, such call will be joining the orbit automatically, from which they retry to get served, after an exponentially distributed time.

Several studies have studied the CRN according to various scenarios. Authors of [3] for example investigated the effect of server unreliability on the CRN. In [6] the same system was used involving abandonment, SUs were forced to leave the system once their total waiting time exceeds a random maximum waiting time. Balking and/or reneging were studied in several queuing systems such as [7–17] and [18]. However, after a thorough search of several related topics and reports, we were unable to locate any articles that addressed this model in the case of balking and reneging, which is the novelty of our investigation.

2 System Model

Figure 1 shows a queueing cognitive radio system based on the following assumptions. Consider two linked subsystems, in which primary requests are created by a finite number of sources N_1 and sent to the first server based on an exponentially distributed time with an average value of $1/\lambda_1$. If the unit is free, the service might start, if it is busy, the call resides at the preemptive priority queue. The service time of the primary users is a exponentially distributed random variable with parameter μ_1.

The number of sources of the secondary subsystem is denoted by N_2. According to an exponentially distributed time with parameter λ_2/N_2, each source produces low priority jobs. With a rate μ_2, the service time of SUs is generally distributed using hypo-exponential, hyper-exponential and gamma distributions, having the same mean and different variances. The secondary customer's retrial time is assumed to be an exponentially distributed random variable with a parameter of ν.

New arriving secondary customers might balk (refuse to join the server) with probability n/N_2 where n is the number of customers in the system and N_2 is the number of sources. After joining, they might also renege (leave the orbit after entering) if service does not begin by a certain random time, which is exponentially distributed with parameter τ.

3 Simulation Results

In this section, the effect of the service times distributions and the impact of the cognitive technology on the key performance measures of our system are investigated. Assuming that all random variables included in the system are exponentially distributed except the services, we created a stochastic simulation

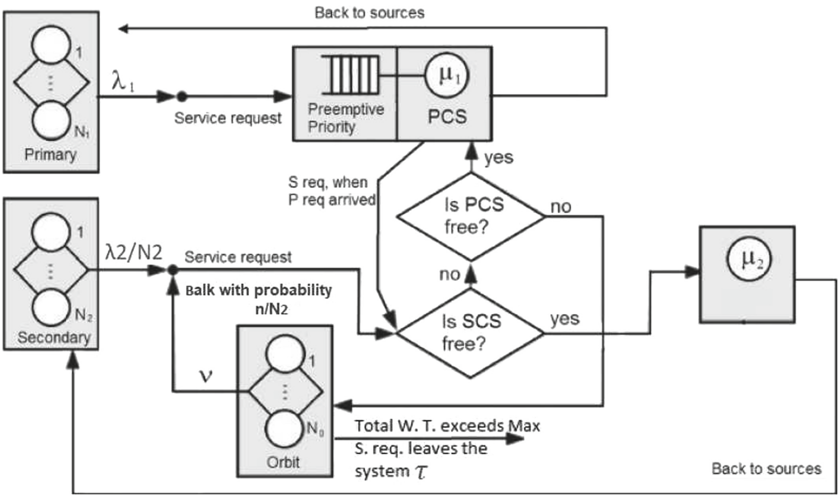

Fig. 1. Finite-source retrial queuing system: Modeling the Cognitive Radio Network with balking and reneging.

program written in C coding language with SimPack [19]. All the numerical results were collected by the validation of the simulation outputs. Table 1 shows the numerical values of the simulation main class input parameters while Table 2 defines the numerical values of the statistical class of the simulation program.

Table 1. Simulation input parameters

N_1	N_2	λ_1	λ_2/N_2	μ_1	μ_2	ν	τ
20	50	0.1	x-axis	1	1	0.1	0.1

Table 2. Parameters of the general distributions

Distribution	Gamma, $c_x^2 < 1$	Hyper	Hypo	Gamma, $c_x^2 > 1$
Parameters	$\alpha = 1{,}7857$ $\beta = 1{,}7857$	$p = 0{,}3309$ $\lambda_1 = 0{,}66198$ $\lambda_2 = 1{,}33803$	$\lambda_1 = 1{,}4854$ $\lambda_2 = 3{,}06$	$\alpha = 0{,}3906$ $\beta = 0{,}3906$
Mean	1	1	1	1
Variance	0.56	2.56	0.56	2.56
c_x^2	0.56	2.56	0.56	2.56

Service Times Are Generally Distributed. Figure 2 illustrates the influence of primary and secondary service times distribution on the mean residence time of SUs versus secondary request time generation. A high distributions sensitivity

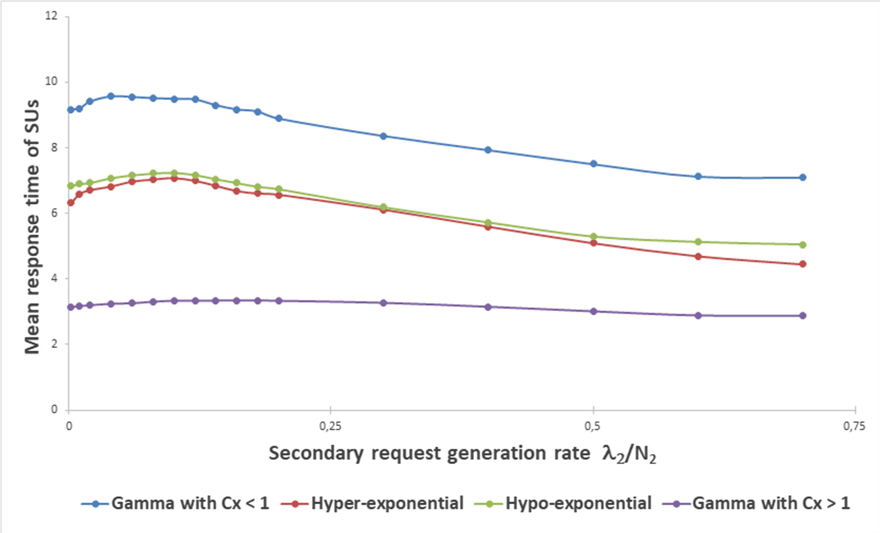

Fig. 2. The impact of primary and secondary service times distribution on the mean residence time of SUs vs secondary request time generation

can be observed when service times are gamma distributed with a squared coefficient of variation greater than one. The same clear sensitivity is seen in Fig. 3, where the effect of primary and secondary service times distribution on the mean reneging time of SUs vs secondary request time generation was displayed, while gamma with a c_x^2 greater than one. This confirms the same behaviour noticed in the previous figure. Furthermore, as anticipated, by increasing the arrival intensity of SUs, it involves greater reneging rate, we note an important number of customers that leave the system, especially in the hypo-exponential case. Table 2 states the parameters of the used general distributions.

The impact of the service times distribution of the primary and secondary subsystems on the mean balking rate versus λ_2 can be observed in Fig. 4. Increasing the secondary arrival rate involves a higher discouragement for new arriving secondary customers, this can be seen clearly in the case of Gamma distribution. It is well known according Gamma distribution function that when $c_x^2 > 1$ the generated random service time is great which leads to an overloading of the system, hence, the figure shows (Table 3).

Figure 5 illustrates The impact of primary and secondary service times distribution on the mean response time of SUs vs primary request time generation. An obvious impact can be seen in this figure especially in the case of having a squared coefficient of variation greater than one. The phenomenon of dealing with primary arrival intensity and investigating the effect of the service time distribution can be also seen in cite.......

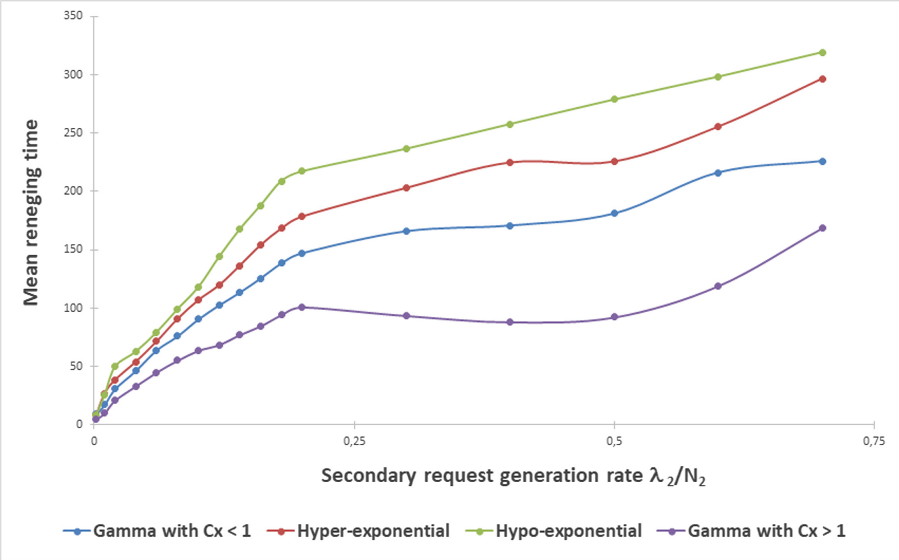

Fig. 3. The impact of primary and secondary service times distribution on the mean reneging time of SUs vs secondary request time generation

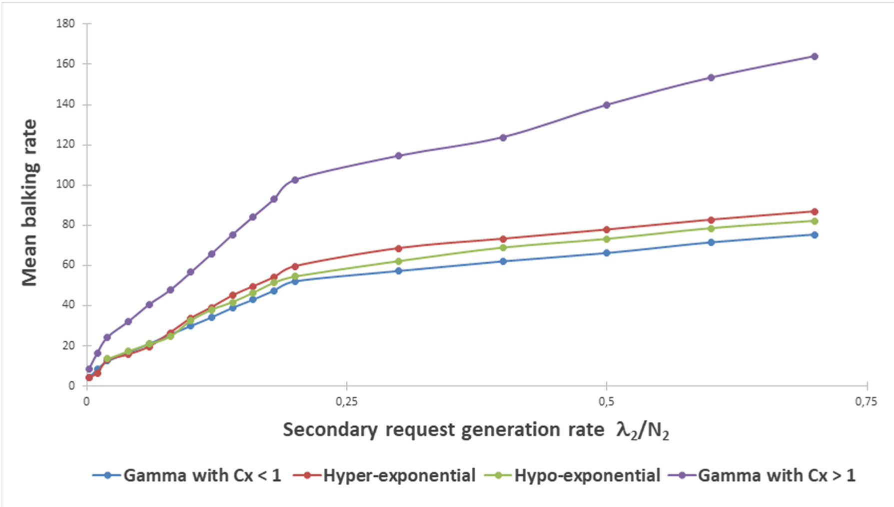

Fig. 4. The impact of primary and secondary service times distribution on the mean balking rate of SUs vs secondary request time generation

Figure 6 was generated to investigate the impact of primary and secondary service times distribution on the mean reneging time of SUs vs primary request time generation. Increasing the primary request generation rate involves a

Table 3. Simulation input parameters for Figs. 5 and 6

N_1	N_2	λ_1	λ_2/N_2	μ_1	μ_2	ν	τ
20	50	x-axis	0.14	1	1	0.1	0.1

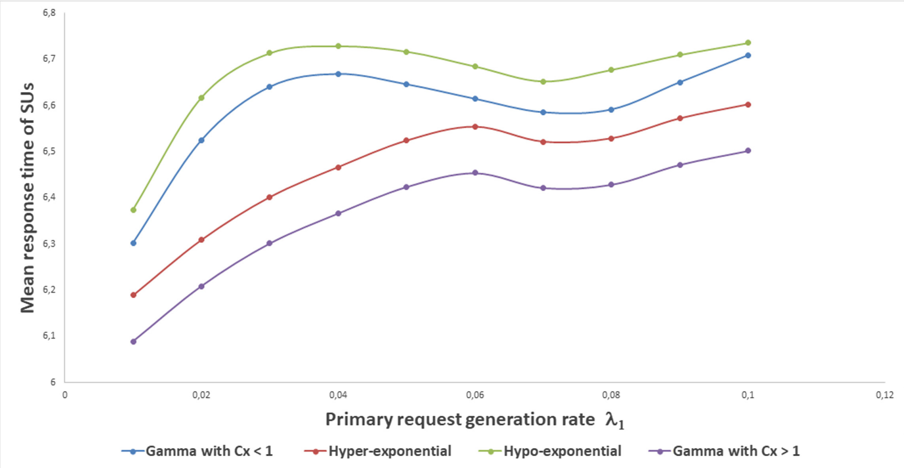

Fig. 5. The impact of primary and secondary service times distribution on the mean residence time of SUs vs primary request time generation

higher mean reneging time, however, using Gamma distribution with a squared coefficient of variation less than one, did not involve a high mean reneging rate as comparing to the rest of the distributions.

All Inter-event Time Are Exponentially Distributed. In this subsection we assume that all inter-event time are exponentially distributed. Same value of the parameters shown in Table 1 are applied with $\lambda_2 = 0.5$. We would like to analyze the impact of the cognitive technology on the characteristics of the system.

Figure 7 shows the impact of the primary arrival rate and the number of sources on the mean sojourn time of cognitive users while increasing N_2. In this figure, we can observe that the primary arrival intensity has an important effect on the average residence time of SUs, as when $\lambda_1 = \lambda_2/2$ the results show a smaller value of the mean than when $\lambda_1 = \lambda_2 \cdot 2$. Unlike the primary number of sources which does not have any effect, as when N_2 is high the traffic intensity in the primary sub-subsystem is bigger. However, in Fig. 8 different impact can be seen, when the primary number of sources is bigger. This is due to more secondary customers are reneging from the system.

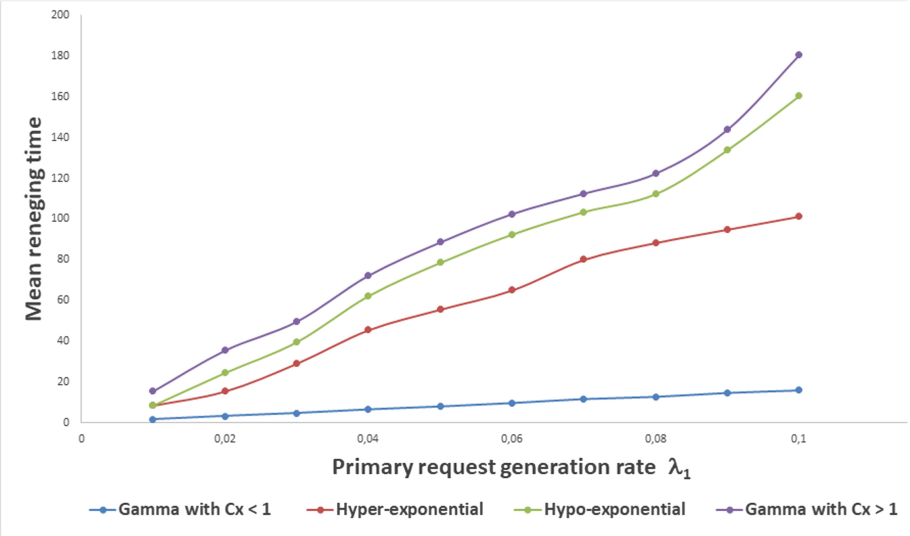

Fig. 6. The impact of primary and secondary service times distribution on the mean reneging time of SUs vs primary request time generation

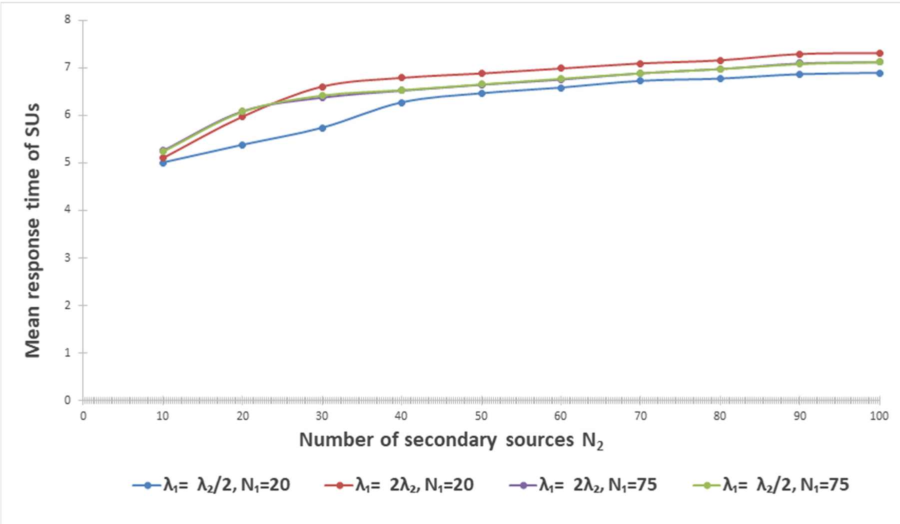

Fig. 7. The effect of the primary network parameters on the mean response time of SUs vs N_2

Figure 9 demonstrates how the primary network parameters can effect the mean response time of SUs vs N_2, the only impact than can be observed when the primary arrival rate is half the secondary's with the few primary sources. This is due to the opportunistic utilization of PCS by SUs, therefore, less customers balk.

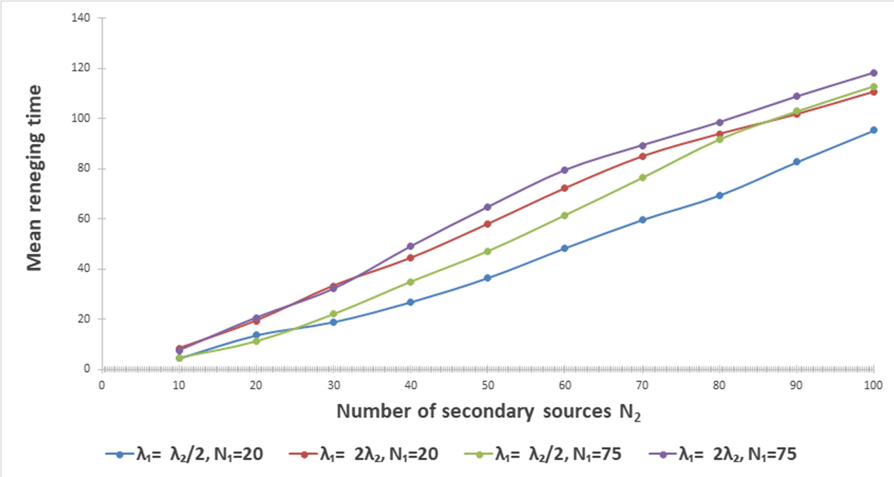

Fig. 8. The effect of the primary network parameters on the mean reneging time of SUs vs N_2

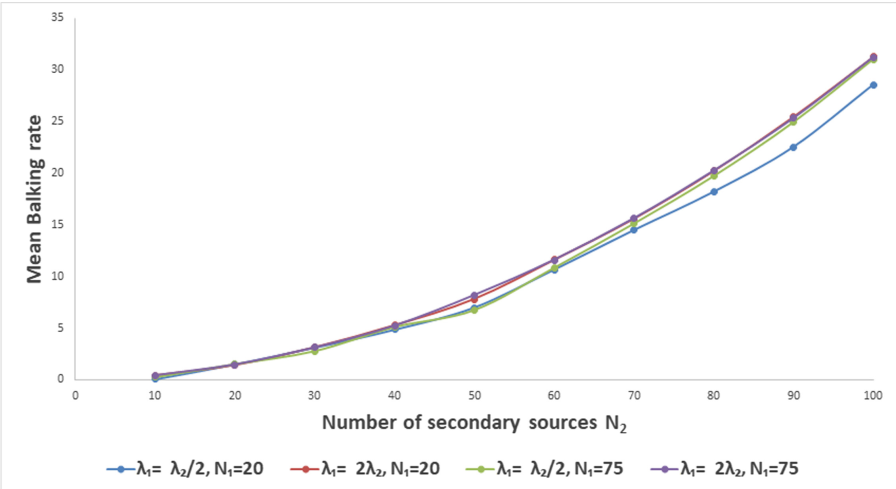

Fig. 9. The effect of the primary network parameters on the mean balking rate of SUs vs N_2

Figure 10 shows the effect of the primary subsystem rates on the mean residence time of cognitive customers vs secondary number of sources. Increasing N_2 provides a higher utilization of the secondary system, however, at same point it reaches the maximum and the server becomes totally full. A clear difference could be found when the primary arrival rate is at its maximum or minimum, $\lambda_1 = \lambda_2 * 2$ and $\lambda_1 = \lambda_2/2$, respectively.

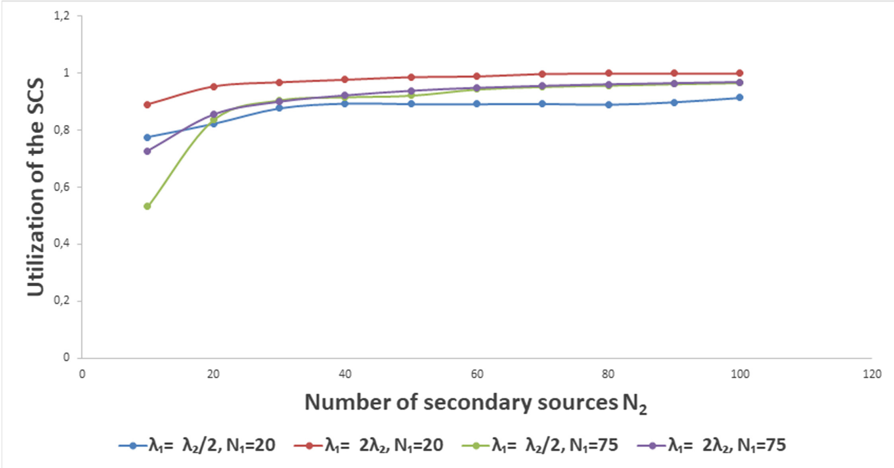

Fig. 10. The effect of the primary network parameters on the utilization of SCS vs N_2

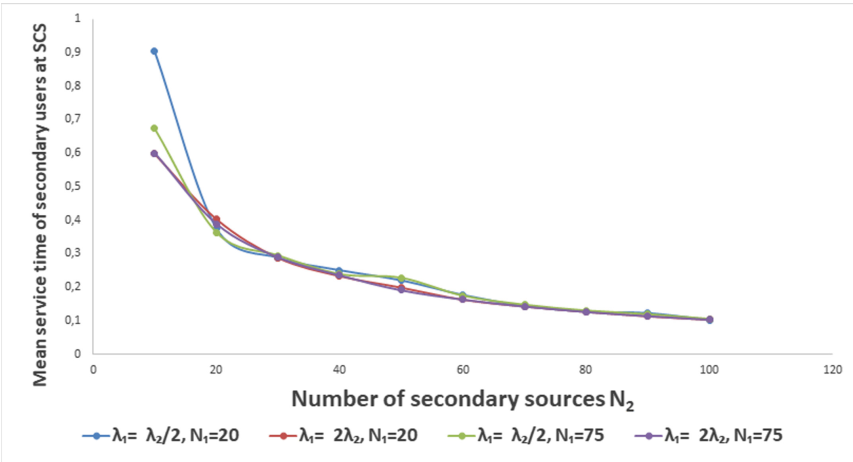

Fig. 11. The effect of the primary network parameters on the mean service time of SUs vs N_2

In Fig. 11 an impact can be seen when we are dealing with a small number of sources ($N_1 = 20$ and $N_2 = 10$). This figure shows how the primary network parameters can effect the mean response time of SUs vs N2.

4 Conclusion

A finite-source retrial queuing system that contains two non-independent parts was introduced in this paper. Our system was built to model a cognitive radio network with primary and secondary service units with balking and reneging on the second part. A thorough review was carried out using simulation to investigate the effect of the service times distributions and the impact of the cognitive technology on the key performance measures of the system. An interesting distributions sensitivity is noticed while $c_x^2 > 1$ using Hyper-exponential. Unlike the case of Hypo-exponential, less sensitivity is found. Furthermore, when all the inter-event times are exponentially distributed, the figures have shown the efficiency of the cognitive radio technique, increasing or decreasing the arrival intensity and the number of sources of primary customers impacts the characteristics of the secondary users of the system.

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